

Patent
Attorney's Docket No. 031211-067

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of)
)
Hans OTT) Group Art Unit: Unassigned
)
Application No.: Unassigned) Examiner: Unassigned
)
Filed: December 7, 2001)
)
For: DEVICE FOR THE PIXEL-BY-)
PIXEL PHOTOELECTRIC)
MEASUREMENT OF A PLANAR)
MEASURED OBJECT)

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination of the above-captioned patent application, kindly enter the following amendment.

IN THE ABSTRACT:

Kindly replace the Abstract with the following:

-- The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means for the imaging of the measured object onto a two-dimensional CCD image sensor, filter means provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured, as well as data

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processing means for the processing of the raw measured data into image data representing the colors of the individual image elements of the measured object. Furthermore, illumination means are provided which include a Fresnel lens, which illuminate the measured object with at least one essentially parallel light bundle under an angle of incidence of essentially $45^\circ +/- 5^\circ$. The projection means which include at least one tele-lens constructed as a Fresnel lens, are constructed as tele-centrical imaging optics, which image each point of the measured object under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle of essentially maximally 5° onto the light converter element array. The data processing means carry out extensive correction measures.--

IN THE SPECIFICATION:

Kindly replace the paragraph beginning at page 2, line 24, with the following:

-- Preferred embodiments of the invention will be described in the following by way of example only and with reference to the drawings, wherein:

Figure 1 is a schematic illustration of a first embodiment of the measurement device in accordance with the invention;

Figure 2 is a schematic sketch of a spectral video camera of a second embodiment of the measurement device in accordance with the invention;

Figure 3 is a sketch illustrating the geometric rectification of the data of the measured object;

Figure 3A is an enlarged portion of Figure 3;

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Figures 4 and 5 show two sketches for illustration of the reflection correction;

Figure 6 is a sketch for illustration of the scattered light correction;

Figure 6A shows an enlarged portion of Figure 6;

Figures 7A and 7B show two test images with respectively one special calibration element;

Figure 8 is a test image with a special scattered light element;

Figure 8A shows the scattered light element of Figure 8 in an enlarged illustration;

Figure 9 is a diagram for the illustration of the calculation of scattered light coefficients; and

Figure 10 is a schematic summary of all correction measures.--

Kindly replace the paragraph beginning at page 4, line 10, with the following:

-- The two flash light sources 4 and 5 are respectively positioned at the focal point of the illumination lenses 42 and 52, so that the measured object M is illuminated with two parallel beam bundles 44 and 54. The positioning is selected such that the angles of incidence α of the two parallel beam bundles are essentially $45^\circ +/- 5^\circ$ to the optical axis of the imaging optics or to the normal 31 of the measured object M. The geometric conditions defined in international standards for the color measurement are thereby complied with.--

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Kindly replace the paragraph beginning at page 5, line 10, with the following:

-- The spectral characteristic of interference filters is dependent on the angle of incidence of the light beams. This angle is not constant but dependent on the position of the measured image points on the measured object. However, it can be calculated from the position of the respective image point and in turn the actual reflective filter characteristic for the respective image point position can then be determined therefrom. The spectral values can be determined by interpolation for the nominal wavelengths, for example, 400, 420, 440.... 680, 770nm. Therefore, the angle dependency of the filter characteristics can be corrected by recalculation. This is further discussed below.--

Kindly replace the paragraph beginning at page 13, line 3, with the following:

-- The position deviations ΔX and ΔY relative to the normal positions (points 301-309) are determined for each of the nine reference points 311-319 as is apparent from Figure 3a. In the next step, the position deviations for each individual image point of the whole test image are calculated by interpolation from the position deviations of the nine reference points. According to experience, the position deviations of closely adjacent image points are not very different. Thus, according to one aspect of the invention, several, for example 8x8 adjacent image points, are respectively combined into a geometry correction region and the position deviations are calculated only for those geometry correction regions. If one assumes a total of 480 x 640 image points, this results in about $60 \times 80 = 4,800$ regions. The (calculated) position deviations Δx and Δy of those 4,800 geometry correction regions are then saved in a geometry correction table. A portion of an

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exemplary geometry correction table is illustrated in Table 3 Δx and Δy values are arbitrary).--

Kindly replace the paragraph beginning at page 13, line 16, with the following:

-- For the geometric correction of the measured object, the geometry correction region to which an image point belongs is determined for each image point (by way of its image point coordinates) and the position deviation Δx and Δy for the respective geometry correction region obtained from the geometry correction table. The actual correction is then carried out in the manner already known in that the measured value of the respective image point is replaced by the measured value of the image point displaced by the position deviation (or by a value interpolated from the surrounding points for non-integer pixel spacings).--

Kindly replace the paragraph beginning at page 13, line 23 (Table 3), with the following:

--**Table 3**

Region Number	Image Points	Δx (in pixel)	Δy (in pixel)
1	x1...x8, y1...y8	3.25	-5.75
2	x9...x16, y1...y8	3.2	-5.7
And so on	and so on	and so on	and so on

Kindly replace the paragraph beginning at page 17, line 19, with the following:

-- The scattered light correction for each image point subtracts from the brightness value (remission value) of the respective image point the distance dependent brightness contribution of all image points surrounding the image point. The brightness contribution ΔR_{ij} , J received by an image point i from an image point j is calculated as $\Delta R_{ij} = k_{ij} * R_j$. R_j is thereby the remission value of the image point j, and k_{ij} is a coefficient depending on the distance between the image points i and j, which of course must be determined beforehand. For an arrangement of $N*M$ image points, which are numbered from 1- $N*M$, the contribution of the surrounding points is calculated as follows for each individual image point i:--

Kindly replace the paragraph beginning at page 17, line 28, with the following:

-- The scattered light corrected remission value R'_i is $R_i - \Delta R_i$. As is easily apparent, $(M*M)^2$ coefficients and a corresponding number of multiplications and additions are required for the calculation of the corrections. For 300,000 image points, the required calculation effort would be gigantic and completely impractical as already mentioned.--

Kindly replace the paragraph beginning at page 21, line 15, with the following:

-- Scattered light correction of individual image regions:--

Kindly replace the paragraph beginning at page 21, line 21, with the following:

-- Determination of the scattered light correction coefficients:--

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Kindly replace the paragraph beginning at page 23, line 4, with the following:

-- By way of numerous test measurements with scattered light elements of different size, it was found that the scattered light influence decreases at a double logarithmic scale at least in some sections and also overall approximately linear with distance. Figure 9 graphically illustrates in a double logarithmic scale an exemplary relationship between scattered light and image point distance measured by way of 8 scattered light elements. The abscissa shows the distance in pixel units, the ordinate the negative logarithm of the relative scattered light influence or the scattered light coefficient. For example, the scattered light coefficient at a distance of around 50 pixels is 10^{-5} ⁹⁹³. At a distance of about 2 pixels, the scattered light coefficient is 10^{-1} ⁵⁶⁴, thus already about 4 orders of magnitude larger.--

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Kindly replace the paragraph beginning at page 23, line 29, with the following:

-- Calibration of the scattered light correction:--

Kindly replace the paragraph beginning at page 24, line 9, with the following:

-- Whereby ΔR represents the total scattered light correction of an image point, $\Delta R_{AB1} \dots \Delta R_{AB6}$ the individual scattered light correction contributions of the individual analysis regions AB₁...AB₆, and G₁...G₆ the previously once determined weighting and calibration factors.--

Kindly replace the paragraph beginning at page 26, line 4, with the following:

-- Spectral correction:--

Kindly replace the paragraph beginning at page 26, line 14 (equation), with the following:

-- $(SP)_k = (IM)_k * (SP)_\gamma$, --

Kindly insert new paragraph beginning at page 26, line 32, as follows:

-- It will be appreciated by those skilled in the art that the present invention can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the invention is indicated by the appended claims rather than the foregoing description and all changes that come within the meaning and range and equivalence thereof are intended to be embraced therein.--

IN THE CLAIMS:

Kindly replace claims 1,12, 14 and 20 as follows.

1. Device for the pixel-by-pixel photoelectric measurement of a planar or flat object to be measured, comprising:

a two-dimensional array of light converter elements for producing electric signals in response to light remitted by the object to be measured;

imaging means for imaging the object to be measured onto the two-dimensional array of light converter elements;

filters provided in the imaging light path for wavelength selective filtering of the measurement light impinging on the light converter elements; signal processing means for processing the electrical signals produced by the light converter elements for converting them into corresponding digital raw measured data; and data processing means for processing of the raw measured data into image data representing the colors of the individual pixels of the measured object, the data processing means being constructed for carrying out a scattered light correction for reducing scattered light influences.

12. Device according to claim 11, wherein the data processing means is constructed for carrying out the calculation of the reflection image at a lower resolution than that of the measured data.

14. Device according to claim 1, wherein the data processing means is constructed for carrying out a white border normalization, whereby for each measurement the brightness of a white border region is determined and the measured data are normalized to the mean brightness of this border region.

20. Device according to claim 18, wherein about 16 bandpass filters of about 20nm bandwidth each are provided which essentially cover the spectral range of 400-700nm.

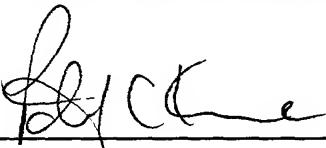
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REMARKS

These amendments were made to place the application in a more suitable form prior to examination. Favorable consideration is respectfully requested.

Respectfully submitted,

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Date: December 7, 2001

Attachment to Preliminary Amendment dated December 7, 2001

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Page 2, Paragraph Beginning at Line 24

Preferred embodiments of the invention will be described in the following by way of example only and with reference to the drawings, wherein:

Figure 1 is a schematic illustration of a first embodiment of the measurement device in accordance with the invention;

Figure 2 is a schematic sketch of a spectral video camera of a second embodiment of the measurement device in accordance with the invention;

Figure 3 is a sketch illustrating the geometric rectification of the data of the measured object;

Figure 3A is an enlarged portion of Figure 3;

Figures 4 and 5 show two sketches for illustration of the reflection correction;

Figure 6 is a sketch for illustration of the scattered light correction;

Figure 6A shows an enlarged portion of Figure 6;

Figures 7A and 7B show two test images with respectively one special calibration element;

Figure 8 is a test image with a special scattered light element;

Figure 8A shows the scattered light element of Figure 8 in an enlarged illustration;

Figure 9 is a diagram for the illustration of the calculation of scattered light coefficients [and]; and

Figure 10 is a schematic summary of all correction measures.

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Page 4, Paragraph Beginning at Line 10

The two flash light sources 4 and 5 are respectively positioned at the focal point of the illumination lenses 42 and 52, so that the measured object M is illuminated with two parallel beam bundles 44 and 54. The positioning is selected such that the angles of incidence [α] of the two parallel beam bundles are essentially $45^\circ +/- 5^\circ$ to the optical axis of the imaging optics or to the normal 31 of the measured object M. The geometric conditions defined in international standards for the color measurement are thereby complied with.

Page 5, paragraph beginning at line 10:

The spectral characteristic of interference filters is dependent on the angle of incidence of the light beams. This angle is not constant but dependent on the position of the measured image points on the measured object. However, it can be calculated from the position of the respective image point and in turn the actual reflective filter characteristic for the respective image point position can then be determined therefrom. The spectral values can be determined by interpolation for the nominal wavelengths, for example, 400, 420, 440.... 680, 770nm. Therefore [Therefor], the angle dependency of the filter characteristics can be corrected by recalculation. This is further discussed below.

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Page 13, Paragraph Beginning at Line 3

The position deviations [C] ΔX and [C] ΔY relative to the normal positions (points 301-309) are determined for each of the nine reference points 311-319 as is apparent from Figure 3a. In the next step, the position deviations for each individual image point of the whole test image are calculated by interpolation from the position deviations of the nine reference points. According to experience, the position deviations of closely adjacent image points are not very different. Thus, according to one aspect of the invention, several, for example 8x8 adjacent image points, are respectively combined into a geometry correction region and the position deviations are calculated only for those geometry correction regions. If one assumes a total of 480 x 640 image points, this results in about $60 \times 80 = 4,800$ regions. The (calculated) position deviations [C] Δx and [C] Δy of those 4,800 geometry correction regions are then saved in a geometry correction table. A portion of an exemplary geometry correction table is illustrated in Table 3 ([C] Δx and [C] Δy values are arbitrary).

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Page 13, Paragraph Beginning at Line 16

For the geometric correction of the measured object, the geometry correction region to which an image point belongs is determined for each image point (by way of its image point coordinates) and the position deviation [⊖] Δx and [⊖] Δy for the respective geometry correction region obtained from the geometry correction table. The actual correction is then carried out in the manner already known in that the measured value of the respective image point is replaced by the measured value of the image point displaced by the position deviation (or by a value interpolated from the surrounding points for non-integer pixel spacings).

Page 13, Paragraph Beginning at Line 23 (Table 3)

Table 3

Region Number	Image Points	[⊖] Δx (in pixel)	[⊖] Δy (in pixel)
1	x1...x8, y1...y8	[3,25] 3.25	-5.75
2	x9...x16, y1...y8	3.2	-5.7
And so on	and so on	and so on	and so on

Page 17, Paragraph Beginning at Line 28

The scattered light corrected remission value R'_i is $R_i - [⊖] \Delta R_i$. As is easily apparent, $(M^*M)^2$ coefficients and a corresponding number of multiplications and additions

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are required for the calculation of the corrections. For 300,000 image points, the required calculation effort would be gigantic and completely impractical as already mentioned.

Page 21, Paragraph Beginning at Line 15

Scattered light correction of individual image regions:

Page 21, Paragraph Beginning at Line 21

Determination of the scattered light correction coefficients:

Page 23, Paragraph Beginning at Line 4

By way of numerous test measurements with scattered light elements of different size, it was found that the scattered light influence decreases at a double logarithmic scale at least in some sections and also overall approximately linear with distance. Figure 9 graphically illustrates in a double logarithmic scale an exemplary relationship between scattered light and image point distance measured by way of 8 scattered light elements. The abscissa shows the distance in pixel units, the ordinate the negative logarithm of the relative scattered light influence or the scattered light coefficient. For example, the scattered light coefficient at a distance of around 50 pixels is $10^{-5.993}$. At a distance of about 2 pixels, the scattered light coefficient is $10^{-1.564}$, thus already about 4 orders of magnitude larger[!].

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Page 23, Paragraph Beginning at Line 29

Calibration of the scattered light correction:

Page 24, Paragraph Beginning at Line 9

Whereby [C] ΔR represents the total scattered light correction of an image point,
[C] ΔR_{AB1} ... [C] ΔR_{AB6} the individual scattered light correction contributions of the
individual analysis regions AB₁...AB₆, and G₁...G₆ the previously once determined
weighting and calibration factors.

Page 26, Paragraph Beginning at Line 4

Spectral correction:

Page 26, Paragraph Beginning at Line 14 (equation)

$$(SP)_k = (IM)_k * (SP)_{\gamma \star}$$

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Marked-up Claims 1, 12, 14 and 20

1. Device for the pixel-by-pixel photoelectric measurement of a planar or flat object to be measured, comprising:

a two-dimensional array of light converter elements for producing electric signals in response to light remitted by the object to be measured;

imaging means for imaging the object to be measured onto the two-dimensional array of light converter elements;

filters provided in the imaging light path for wavelength selective filtering of the measurement light impinging on the light converter elements;

signal processing means for processing the electrical signals produced by the light converter elements for converting them into corresponding digital raw measured data; and

data processing means for processing of the raw measured data into image data representing the [colours] colors of the individual pixels of the measured object, the data processing means being constructed for carrying out a scattered light correction for reducing scattered light influences.

12. Device according to claim [28] 11, wherein the data processing means is constructed for carrying out the calculation of the reflection image at a lower resolution than that of the measured data.

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Marked-up Claims 1, 12, 14 and 20

14. Device according to claim 1, wherein the data processing means is constructed for carrying out a white border [normalisation] normalization, whereby for each measurement the brightness of a white border region is determined and the measured data are normalized to the mean brightness of this border region.

20. Device according to claim 18, wherein about 16 bandpass filters of about 20nm bandwidth each are provided which essentially cover the spectral range of 400-700nm.

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Marked-up Abstract

-- The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means [(3,21)] for the imaging of the measured object [(M)] onto a two-dimensional CCD image sensor [(22)], filter means [(66)] provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means [(23)] for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured [(71)], as well as data processing means [(7)] for the processing of the raw measured data into image data [(72)] representing the colors of the individual image elements of the measured object. Furthermore, illumination means [(4,41-43; 5,51-53)] are provided which include a Fresnel lens [(42:52)], which illuminate the measured object [(M)] with at least one essentially parallel light bundle under an angle of incidence [α] of essentially $45^\circ +/- 5^\circ$. The projection means which include at least one tele-lens [(3)] constructed as a Fresnel lens, are constructed as tele-centrical imaging optics [(3,21)], which image each point of the measured object [(M)] under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle [α] of essentially maximally 5° onto the light converter element array [(22)]. The data processing means [(7)] carry out extensive correction measures.--

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Abstract

The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means for the imaging of the measured object onto a two-dimensional CCD image sensor, filter means provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured, as well as data processing means for the processing of the raw measured data into image data representing the colors of the individual image elements of the measured object. Furthermore, illumination means are provided which include a Fresnel lens, which illuminate the measured object with at least one essentially parallel light bundle under an angle of incidence of essentially $45^\circ \pm 5^\circ$. The projection means which include at least one tele-lens constructed as a Fresnel lens, are constructed as tele-centrical imaging optics, which image each point of the measured object under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle of essentially maximally 5° onto the light converter element array. The data processing means carry out extensive correction measures.

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